

VOLVO

Battery Technology R&D in the Volvo Group

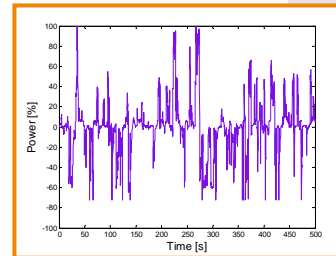
EDC 2010
2010-11-23

Jens Groot

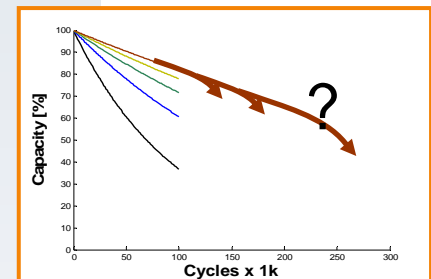
Volvo Technology Corporation //
Chalmers University of Technology

Outline

- Heavy-duty HEVs
 - R&D Strategy - HEVs
 - Challenges
- Energy Storage R&D
 - Model development
 - Method development
 - Cyclelife testing
 - SOH modelling
 - Outlook – future work



$$j = j_0 \left[e^{\frac{\alpha_a F \eta}{RT}} - e^{-\frac{\alpha_c F \eta}{RT}} \right]$$



Heavy-Duty HEVs

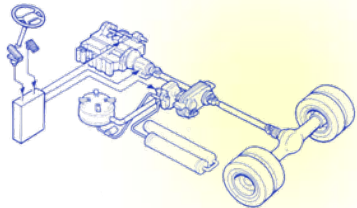
-demonstrators & Concept studies



Diesel electric series



Diesel electric parallel



Diesel hydraulic



Turbine electric series



Diesel electric parallel

Advanced engineering

Industrialization

1985

1995

2005

2010

Heavy-Duty HEVs

-industrialisation & new concept studies

Plug-in HEVs?

EVs?

Industrialisation

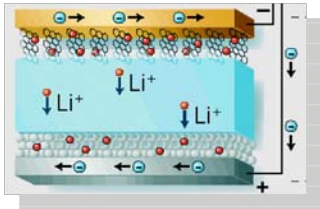


2010

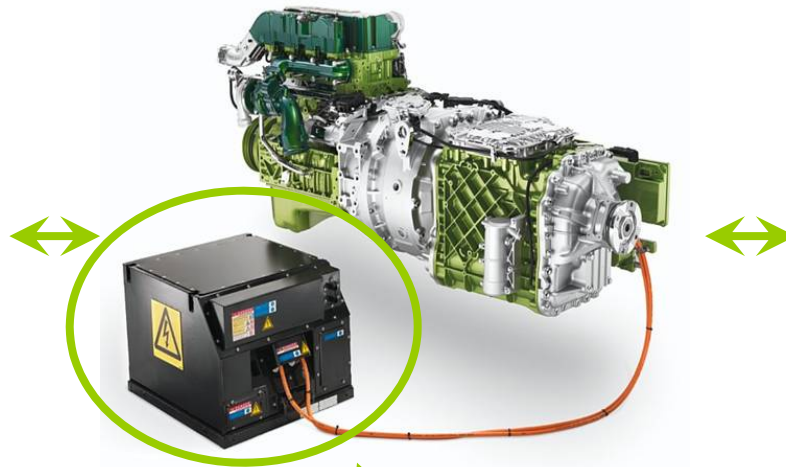


Energy Storage Challenges

- we must understand the entire chain



Explore New Technologies



This is our opportunity
Functionality and usage



Application Improvements

Vehicle Design



ESS Properties

- BMU functionality
- Temperature range
- SOC range
- Power & Energy

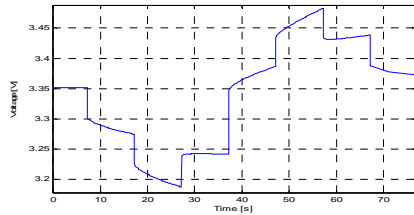
- Gain system knowledge
 - Stratified cell- and system testing
 - **Develop in-house SOC and SOH estimation strategies**
- Understanding rather than assumption
- Optimisation for different applications



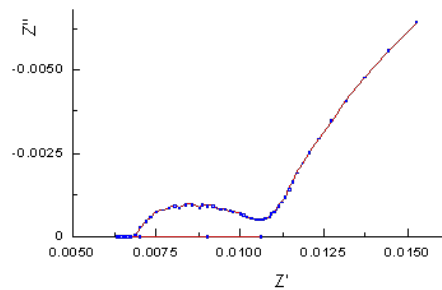
Energy Storage R&D

-Model development

Large-signal response



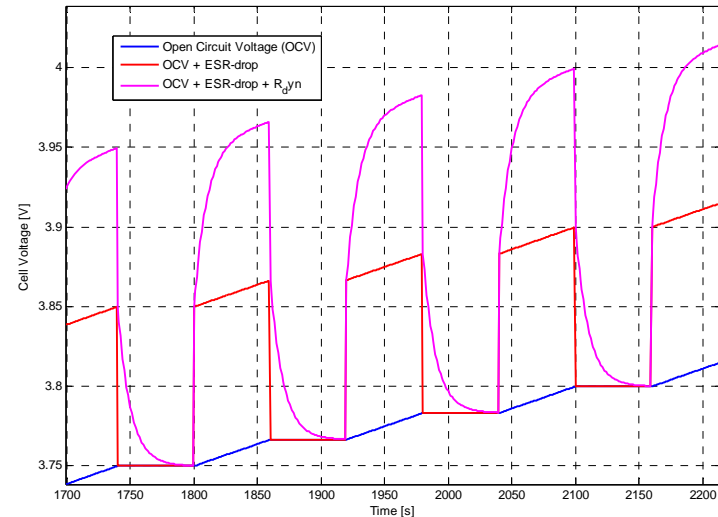
Small-signal response



Theoretical models

$$j = j_0 \left[e^{\frac{\alpha_a F \eta}{RT}} - e^{-\frac{\alpha_c F \eta}{RT}} \right]$$

$$j = -F \sum_i D_i z_i \frac{\partial C_i}{\partial x} - F \frac{\partial \Phi}{\partial x} \sum_i \frac{z_i}{|z_i|} \mu_i C_i + F v \sum_i \mu_i C_i$$

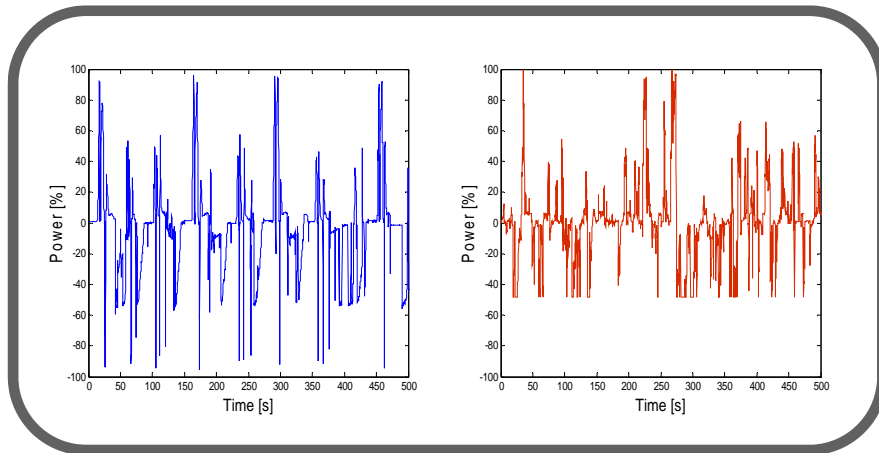


- Empirical Model – linked to electrochemistry
- Equivalent circuit – real-time simulation
- Variable complexity

Energy Storage R&D

-Cyclelife Testing: Load Cycle Analysis

Load Cycle Analysis



Stochastic Markov Model

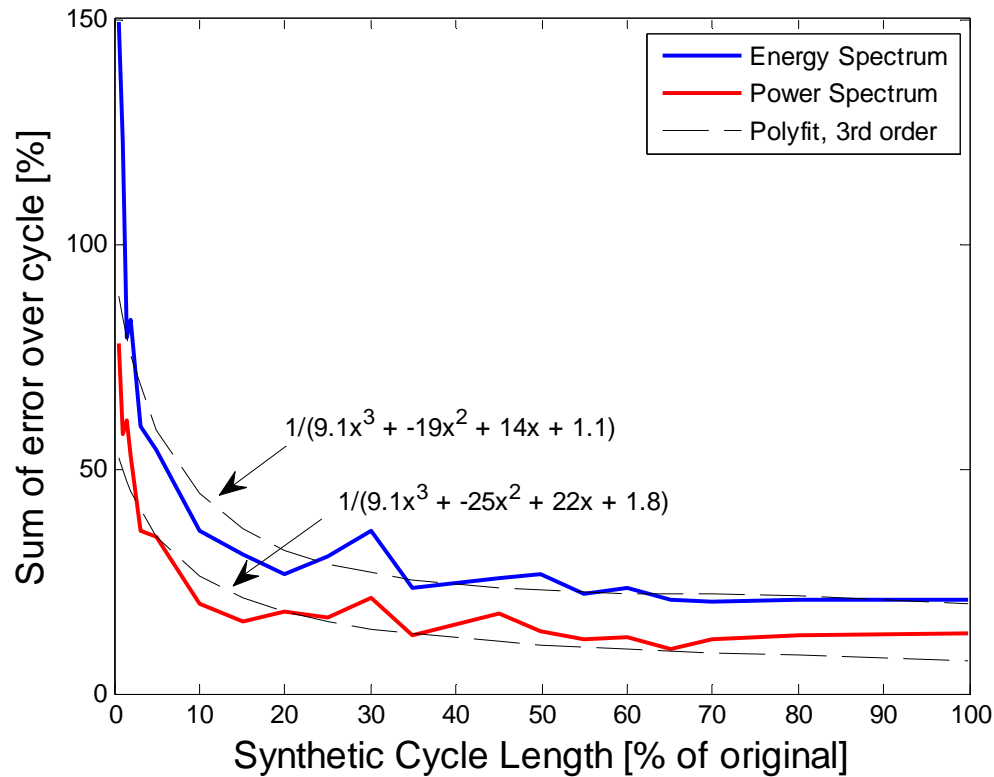


$$Q_{ij} = \begin{bmatrix} S_1 \rightarrow S_1 & S_2 \rightarrow S_1 & \cdots & S_n \rightarrow S_1 \\ S_1 \rightarrow S_2 & S_2 \rightarrow S_2 & \cdots & S_n \rightarrow S_2 \\ \vdots & \vdots & \vdots & \vdots \\ S_1 \rightarrow S_m & S_2 \rightarrow S_m & \cdots & S_m \rightarrow S_m \end{bmatrix}$$

Energy Storage R&D

-Cyclelife Testing: Load Cycle Analysis

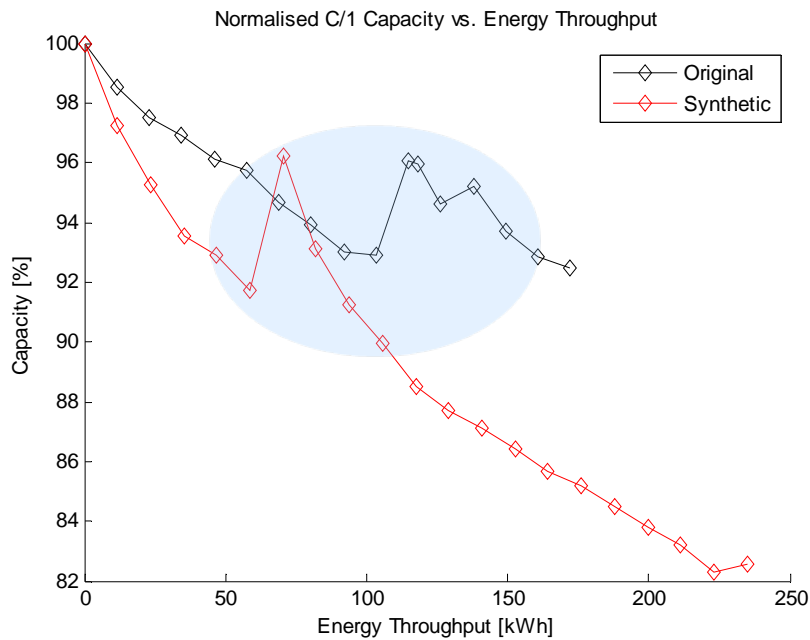
Load Cycle Synthesis



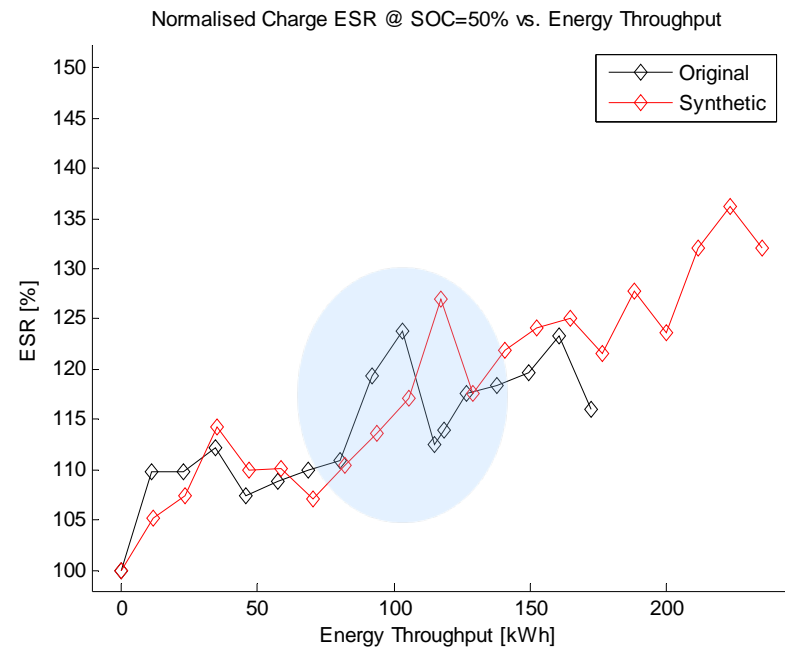
Energy Storage R&D

-Cyclelife Testing: LiFePO_4 // Graphite

Capacity Analysis



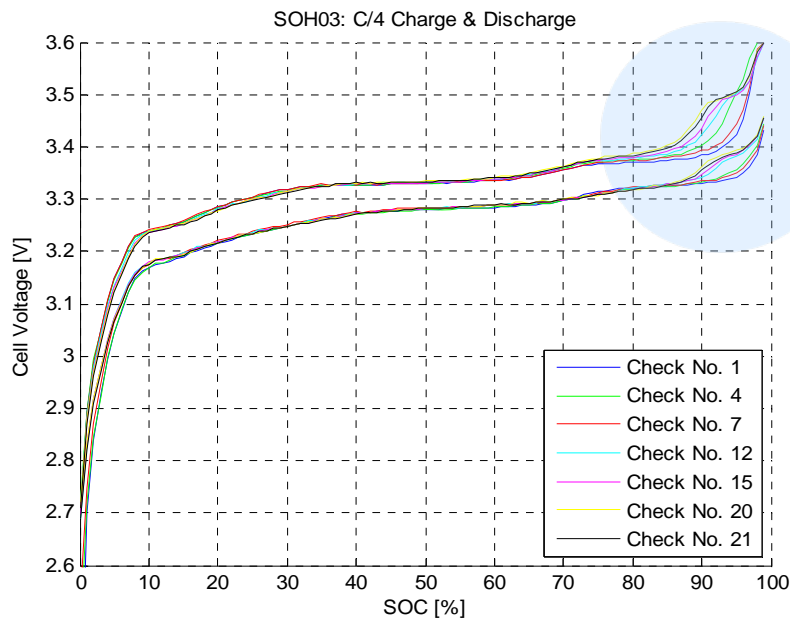
Power & IR Analysis



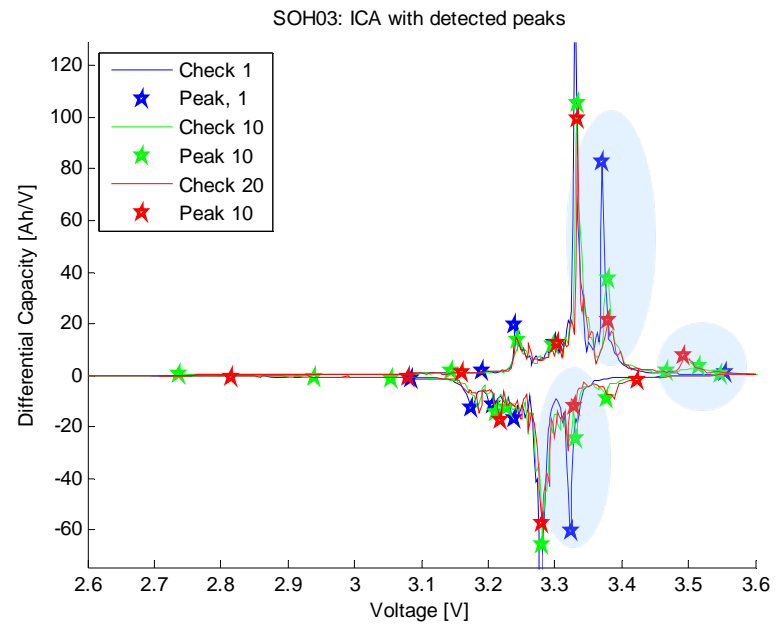
Energy Storage R&D

-Cyclelife Testing: LiFePO_4 // Graphite

Voltage Profile Analysis

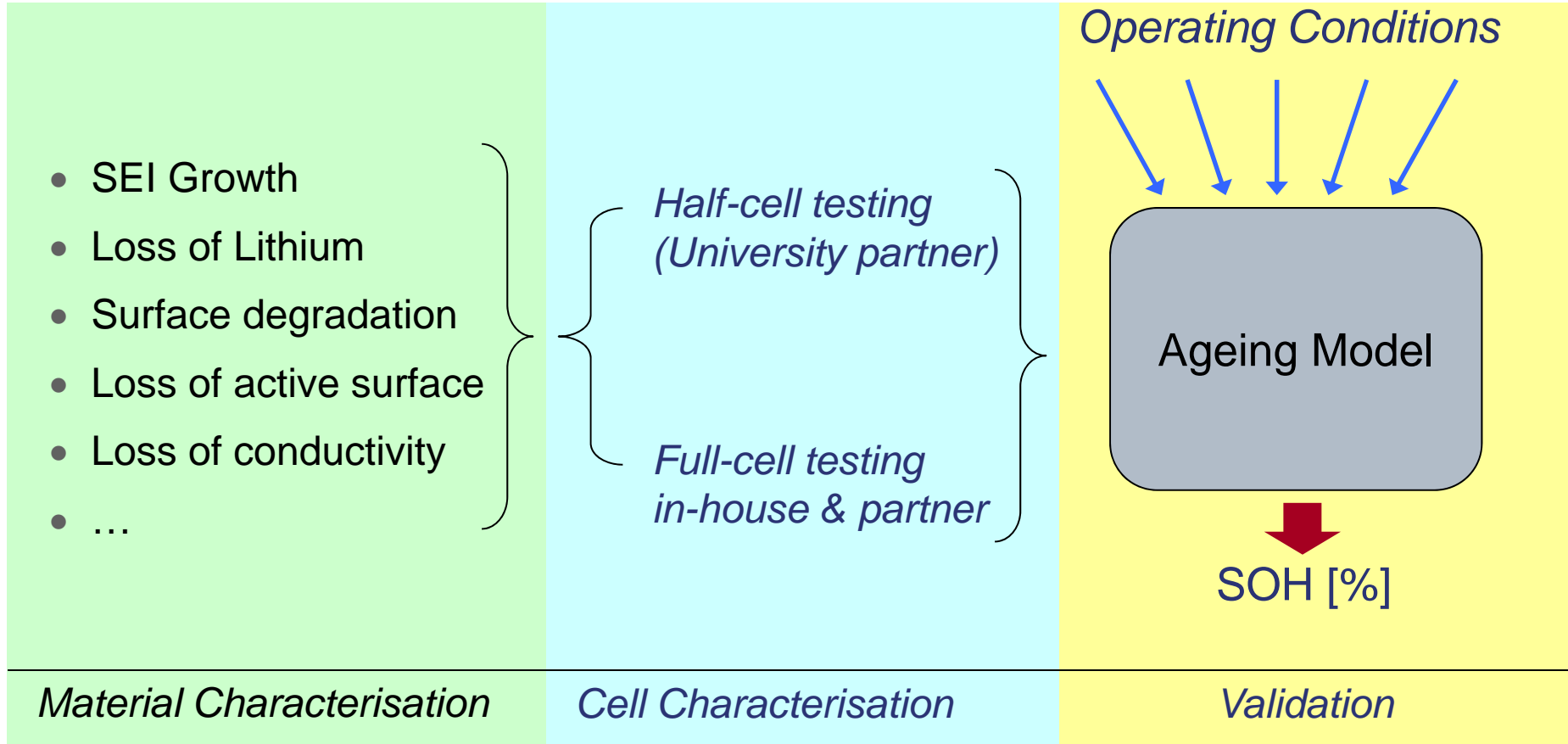


Incremental Capacity Analysis



Energy Storage R&D

-SOH Modelling



Energy Storage R&D

-SOH Testing: next step

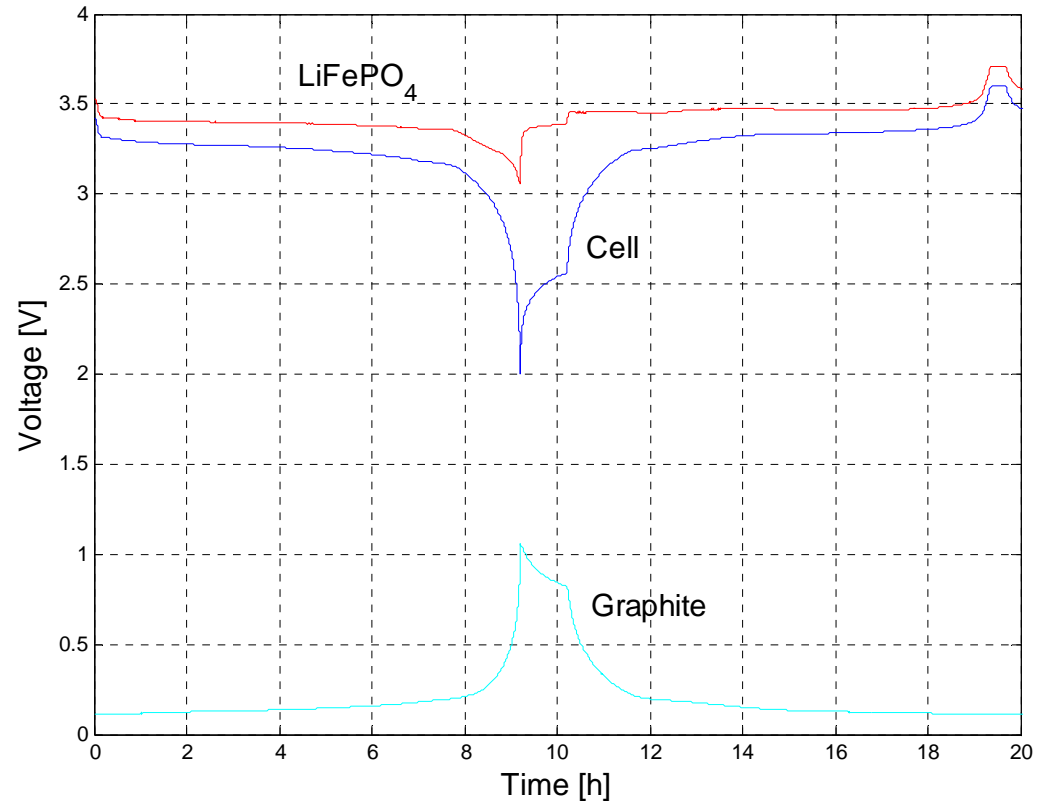
- Extensive Testing
- 3-electrode cell testing
- Modeling specific ageing processes
- 1D/2D Electrochemical model development
- Validation



Energy Storage R&D

-SOH Testing: next step

- 3-electrode cell testing
 - Lithiated LTO reference electrode ($\text{Li}_4\text{Ti}_5\text{O}_{12}$)
 - Enables individual electrode monitoring
 - Custom built cell, 1.9 Ah



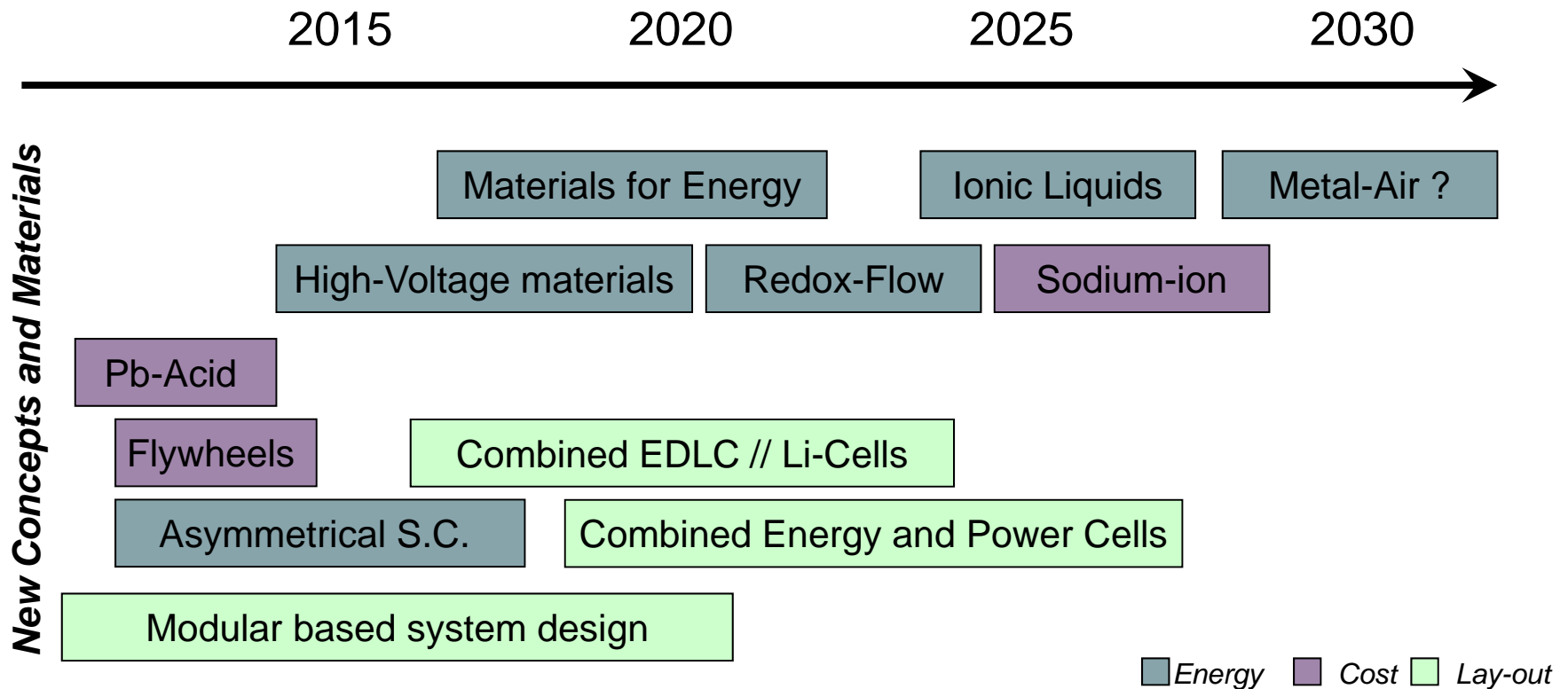
Energy Storage R&D

-SOH Testing: next step

- Testing of commercial cells
 - Standard production cell, 2.3Ah
- $SOH = f(\dots)$
 - Temperature
 - SOC range
 - Average SOC
 - Average power
 - Load cycle selection
 - ...



R&D Outlook – possible areas of interest



Thank you for your attention!

Contact:

jens.groot@volvo.com

jens.groot@chalmers.se